# Fundamentals of Total Quality Leadership

# Module 3: System of Profound Knowledge

Lesson 3: Variation

#### **Instructor Information**

#### **Lesson Outline**

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#### **Lesson Objectives**

By the end of this lesson to student will be able to:

- EO 3-12 Describe the concept of variation.
- EO 3-13 Explain the significance of the quality loss function.
- EO 3-14 Explain the importance of continuous process improvement for reducing variation.
- EO 3-15 Describe the difference between common and special causes of variation.
- EO 3-16 Describe the difference between specification limits and control limits.
- EO 3-17 Describe the difference between stable and capable processes.
- EO 3-18 Explain who is responsible for taking action on common cause and special cause variation.

#### **Length of Instruction**

# **Instructor Information (continued)**

#### **Methods of Instruction**

Lecture, videotape, exercise, and discussion

## Media Required

Overhead projector, screen, video cassette recorder, television monitor, chartpack, and felt-tip pens

#### **Exercise Materials**

Red Bead Exercise Kit

**Note:** An alternative to conducting the Red Bead Exercise would be to show the videotape <u>The Red Bead Experiment and Life</u>. You may also show the optional videotape (<u>Lessons of the Red Bead Experiment</u>). See the Exercise Materials section below and on page xv for details.

After you have conducted the exercise or watched it on videotape, conduct a class discussion covering the lessons learned. Once the discussion is completed, you have an option of showing a videotape which discusses the lessons learned (Lessons of the Red Bead Experiment). The lessons-learned videotape should not be substituted for the class discussion.

#### **Videotapes**

<u>Continuous improvement, The Batavia Incident</u> Ford Communications Network. (1982). [Videotape]. Dearborn, MI: Ford Motor Company. (Time: 15 minutes)

<u>The Red Bead Experiment and Life</u> Crawford-Mason, C. (Producer) & Dobyns, L. (Journalist). (1988).[Videotape, The Deming Library, Volume VII]. Washington, DC.: CC-M Productions. (Time: 25 minutes)

<u>Lessons of the Red Bead Experiment</u> Crawford-Mason, C. (Producer) & Dobyns, L. (Journalist). (1988).[Videotape, The Deming Library, Volume VIII]. Washington, DC.: CC-M Productions. (Time: 25 minutes)

#### **Additional Readings**

<u>Understanding variation.</u> Nolan, T.W., & Provost, L.P. (1990, May). Quality Progress, 23 (5), 70-78.

<u>Don't touch that funnel.</u> Boardman, T.J. and Boardman E.C. (1990, December). Quality Progress.

# Fundamentals of Total Quality Leadership

Module 3

**System of Profound Knowledge** 

Lesson 3

**Variation** 

# **Fundamentals of Total Quality Leadership (FTQL)**

# Module 3 - System of Profound Knowledge

#### **Lesson 3 - Variation**

You will learn the importance of understanding variation -- what it is and its effect on processes. You'll learn about Walter Shewhart's contributions to managing process variation. From this, you'll see that there are two ways of classifying variation, and you'll learn who is responsible for taking action to reduce variation. This lesson includes the Red Bead Exercise, which demonstrates concepts that are important to understanding TQL.

# **Learning Objectives**

#### At the end of this lesson the student will be able to:

- Describe the concept of variation
- Explain the significance of the quality loss function
- Explain the importance of continuous process improvement for reducing variation
- Describe the difference between common cause and special cause variation
- Describe the difference between specification limits and control limits
- Describe the difference between stable and capable processes
- Explain who is responsible for taking action on common and special cause variation

## **Learning Objectives**

By the end of this lesson the student will be able to:

#### **♦** Describe the concept of variation

You will learn about the concept of variation -- that variation affects everything we do. Variation affects the quality of what we produce and the services we provide to our customers.

# **♦** Explain the significance of the quality loss function

The quality loss function will be introduced for the purpose of understanding the relationship between decreasing quality and increasing cost. Although the quality loss function as we study it today has been around since the 1940s, its importance is only now being appreciated by American managers.

# Explain the importance of continuous process improvement for reducing variation

You will learn why "fixing a problem" is not sufficient if organizations are going to survive. Instead, organizations must practice continuous process improvement. This is essential for reducing variation and for the success of any organization.

## Describe the difference between common cause and special cause variation

To practice continuous process improvement, you must have a clear understanding of the difference between common and special causes of variation. Understanding this difference helps determine when or when not to take action on processes.

#### Describe the difference between specification limits and control limits

You will see why relying on design specifications does not ensure producing a quality product. You will learn that a better approach to obtaining quality is achieved by using control limits to tell us if our processes are able to meet the quality expectations defined by our customers.

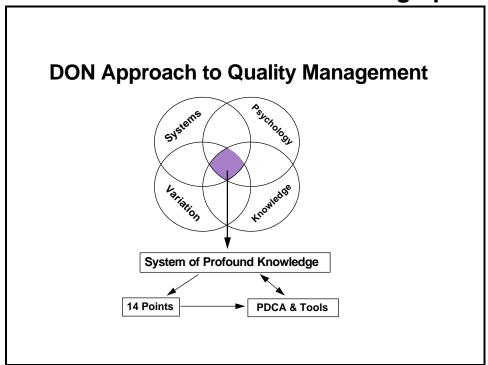
# Describe the difference between stable and capable processes

You will learn what is meant by a capable process, that is, whether or not our processes are consistently producing the organization's products or services to the quality level defined by our customers.

# Explain who is responsible for taking action on common and special causes of variation

To produce quality, action must be taken on the causes that interfere with achieving quality. You will learn who is responsible for taking action to eliminate unwanted variation in work processes. You will also learn the relationship between these actions and the roles of the quality improvement teams.

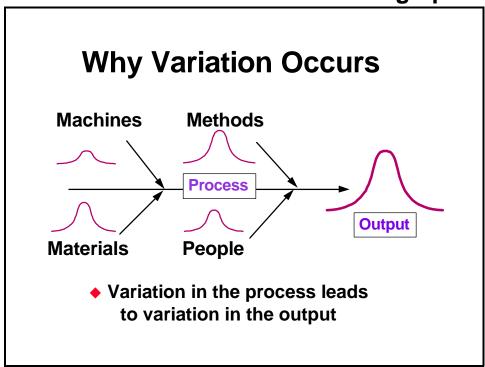
In this module, you will see some videotapes to illustrate many of the lesson's objectives. From the videotapes and follow-up discussions, you will learn why understanding the concept of variation and knowledge about reducing variation is essential to the meeting the needs of our customers.



# **DON Approach to Quality Management**

In Module 3-1 (Systems), you learned you need to understand something about the nature of systems to optimize our organizations. To understand what is happening in the system, we must first study the variation that exists in the system. Until we study this variation, we cannot begin to know when or how to improve our processes to optimize our system. Thus, the areas of variation and systems are intertwined in the meaning and understanding of profound knowledge. In this lesson, the focus is on the concept of variation and its relationship to process improvement as a way to increase quality.

★ Additional Information: According to Cowles (1989), the concept of variation originates from the field of biology where scientists observed variation in the different species. As the machine age evolved, the concept of variation was applied to machine studies. Machine operators found that each machine seemed to have a personality of its own. In other words, the operating characteristics (and resulting outputs) exhibited some degree of variation from machine to machine.



# **Why Variation Occurs**

We saw a variation of this diagram in Module 1 (DON Quality Approach) when we talked about processes. It shows the various process causes coming together to produce an output (product or service).

Instructor Direction: Before discussing this viewgraph, you may want to conduct an exercise to introduce the concept of variation. Ask each student to do the following:

- 1. Write down his/her own first name four times.
- 2. Ask each student to compare his/her four signatures to see how much variation occurred among the four signatures.
- 3. Now ask the students to repeat the exercise, but this time they are to make each signature identical.
- 4. Ask the students if the signatures are identical. (They might be very similar, but they won't be identical.)

#### ◆ Variation in the process leads to variation in the output

A law of nature states that there is variation in everything. For example, no two snowflakes are alike. The variation may be obvious, or it might require sensitive instruments to detect, but the variation will be there.

For example, how often have you sorted through a bin of apples to pick out the ones that exhibit the least amount of variation in the quality characteristics that are important to you? When selecting apples at the market, you probably consider such things as color, size, and firmness in making your selection. The variation seen is a result of the process used in growing, selecting, packaging, and delivering the apples to the market.

Variation occurs in manufacturing. How often have you had to try on more than one pair of the same brand slacks to find the pair that fits you best? Again, the piece-to-piece variation seen in what are supposed to be identical items (slacks) is due to the variation that exists in the process used to manufacture the slacks.

As with manufactured products, no two services are provided exactly the same. How crisp the french fries are at your favorite fast food restaurant, how your laundry is folded by the cleaners, the time that the mail is delivered, or how efficiently a purchase order is filled out all show some degree of variation. Again, the variation is the result of the process used in providing the service. All the variables that affect the outcome of any process is referred to as a **cause system**.

We observe variation all around us and use this information to plan our lives and our work. The information helps us meet some of our expectations, accomplish our goals, and predict what will happen in the future. If we know how to study variation, then we can understand its causes, be prepared for the variation that occurs, and use the information to improve our lives and the processes that make up our organizational system.

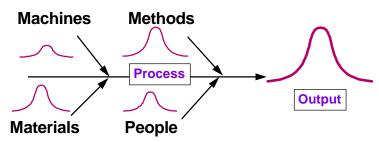
Ultimately, you need to take a different view of your system and the processes that make up your system. By understanding variation, you can begin to reduce the variation in processes. This reduces the variation in the output -- resulting in higher quality products and services.

Instructor Direction: Ask the students to describe examples of variation that occur in their work environment. Have them describe all the sources of variation they can think of.

#### ★ Additional Examples :

- (a) The curve labeled "output" could represent the distribution in the size of a mechanical part in a ship's gun turret. The variation in the output may result in a part fitting too tightly or too loosely, either of which may cause excessive wear in the turret (outcome). Looking backward in the process, you would see that different causes contribute to the variation in the process used to construct the mechanical part.
- (b) What about variation in how close Marines can navigate to a ground position? Causes of variation in their accuracy could be due to the appropriateness of the map scale and contour interval (material), their ability to interpret the map (people), the reliability of the compass (machine), the methods they use to figure out their position (methods), and the weather conditions (environment).
- (c) If you are asked to write a report, the variation in time it takes will depend on any number of variables. These variables could include how well the computer is functioning (machine), the individual typing speed and thought processes (person), the method (methods) by which you outline and organize the information for the report, and the room temperature (environment).
- (d) When practicing a golf swing on the driving range, the length of a golfer's drive varies each time the ball is hit. The golfer may not consciously think about "how much variation there is" in the length of the drive, but this variation occurs and is due to many factors. The condition of the ball (material), the manner in which the club is held and swung (method), the golfer's energy level or attitude on any particular day (person), the club itself (machine), the location and height of the trees (environment) and other causes are all variables that affect the output of the drive.
- (e) What about production? If you produce golf balls, the variation in the quality of the ball, that is, how far the ball will go when hit, depends on such things as the material from which the ball is made (material), the consistency in the operation of the machines that make the ball (machine), the skill and attention provided by the worker (person), and the methods of production (methods). These factors all cause variation in the quality of the golf ball (output).

# **Shewhart's Discovery**



- Variation is inherent in all processes
- Process causes can be identified, measured, and analyzed
- Deliberate action is required to reduce variation

# **Shewhart's Discovery**

To understand variation, we need to be familiar with the work of Walter Shewhart (1924).

## ♦ Variation is inherent in all parts of a process

Shewhart observed variation in process causes and outputs and studied this variation. By taking repeated measures, he found that variation always occurred -- in the process causes and in the process output. The only thing that was constant was the existence of variation itself.

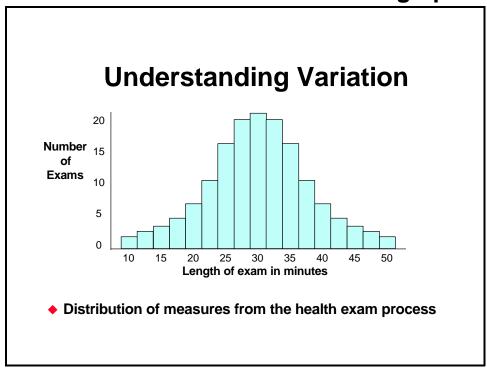
# ◆ Process causes can be identified, measured, and analyzed

Process causes (machines, methods, materials, and people) are the factors causing variation within a process. In his studies, Shewhart found that **each process cause can be identified, measured, and analyzed**. By reducing variation in the process causes, you reduce the variation in the output (product or service), so you are better able to meet the customer's quality expectations.

### ◆ Deliberate action is required to reduce variation

Once you identify the causes of variation, you must take deliberate action on those causes, based on the data, to reduce the variation . This action must be taken systematically and by the appropriate level of responsibility.

★ Additional Information: In all organizations, variation takes place in systems established by management. However, knowledge about the concept of variation has not been a part of traditional management curriculums. Leaders and managers must learn to manage the cause system of variation (machines, methods, materials, and people) to ensure producing quality products and services.



# **Understanding Variation**

Variation means to be different from one occurrence to another. One way of illustrating these differences is by charting the measurements obtained from the various occurrences. The distribution of these measures can be plotted on a graph to show the range of variation. This graphic representation of the variation is called **frequency distribution**.

An example of a typical frequency distribution is shown in this viewgraph by the **vertical bars** (histogram). Data were collected on how long it takes for a routine annual physical exam to be conducted by the family physician. Most of the physical exams take about 30 minutes.

The measures vary around the average value, which in this case, is 30 minutes. How much variation is occurring and why it is occurring needs to be understood.

When the measures vary around a central point, it is common to obtain a distribution that resembles a bell-shaped curve represented by the shape of the histogram.

How does variation relate to our customers? In this example, the data (measures) show that the patients can expect their exams to last about 30 minutes and exams are scheduled accordingly. When exams take longer than this, other patients (customers) have to wait for the doctor. Conversely, if less time is taken for exams, the doctors may get ahead of schedule and have to wait for patients to arrive to see them. Underutilized resources (doctors in this case) drive up costs.

The patient has an expectation of how long the exam will take. Patients sometimes think that all delays are caused by the doctor. The doctor, however, is only one part of the process causes (people) having an effect on the output. Perhaps the variation is due to poorly functioning diagnostic equipment (machines), inadequate supplies (materials), or any number of other causes that may contribute to the variation in the length of the exam procedure.

Traditional management practices might call for directing doctors to reduce the amount of time spent with each patient without understanding what causes are contributing to the variation in exam times. This might result in skipping essential parts of the exam, missing symptoms, an incorrect diagnosis -- all of which decrease the quality of the service (exam). Obviously, this approach causes inefficiencies and increases waste which ultimately increases the cost of doing business.

# ★ Additional Example :

On a destroyer with a crew of 350, you can plot the number of times the mess hall provides the exact number of servings needed to feed the crew, and how many times the galley exceeds or fails to provide the required number. If the galley consistently prepares 350 servings, everyone will be happy. If not enough servings are provided, some ship's crew may have to eat cold cuts instead of the hot meal. On the other hand, if too many servings are provided, the extra food will be thrown away, causing waste or a possible later shortage of ingredients.

★ Additional Information: Students sometimes ask if all distributions exhibit a symmetrical curve (bell-shaped). The answer is no. The following describe differently shaped distributions and reasons why they might occur.

A **bimodal distribution** occurs when observations from two different populations with different mean values are shown as one distribution. For example, the heights of students in the classroom could create a bimodal distribution where the mean height of the males would be different than the mean height of the females. Another example might be if you compared two different suppliers, each delivering an order of one-inch rivets.

A **skewed distribution** occurs when the mean value is located far to one side of the distribution. It can be either left-skewed or right-skewed. This type of distribution can occur when "defective" items have been inspected out. As another example, this can occur when the greatest number of products being produced falls at one end of the specification resulting in the mean value being located on one side and not in the center of the distribution.

An **isolated-peak distribution** occurs when there are two mean values. This can occur, for example, when there is an error in one of the measurements.

However, without collecting data, you cannot know the distribution -- information that lets us plan.

# Video...

# "Continuous Improvement: The Batavia Incident"

Video: "Continuous Improvement: The Batavia Incident"

**♦ Video**: Show the video, "Continuous Improvement: The Batavia Incident."

Time: 15 minutes

You are now going to see a video produced by the Ford Motor Company that shows how a Japanese company (referred to as the "offshore competition") understood and took advantage of what Shewhart had discovered about variation and what an American company (Ford) had to learn.

You will see Ford engineers studying a component of an engine transmission. Because of a heavy workload, Ford had contracted out the production of transmissions to an offshore plant. The transmissions from the offshore plant operated very smoothly and required few warranty repairs. In contrast, the transmissions built in the Ford plant were plagued with warranty repairs. This video shows a key difference between the Ford and off-shore approaches to achieving quality. Each system had different aims.

Instructor Direction: Before showing the video do the following:

- Tell the students that Ford had been tracking its warranty repair costs and noticed a significant difference between the two plants that produced the same transmission. They undertook a study to find out why. Ford produced this videotape in 1984. The offshore plant referred to in the videotape is not specifically identified, but it is a Ford/Japanese facility.
- 2. Tell the students to observe the attitude of the shop leader and the thoughts he has about the measuring equipment.
- 3. Tell the students they will hear the following terms in the videotape: specification, conformance, tolerance, blueprint, built-to-print, and parts-to-print. Explain that these terms are different ways of saying that products (parts) are built to specific engineering design requirements.

**Specifications** provide numerical values for requirements, dimensions, materials, and so on for the parts being produced. In the videotape, Ford is looking to see if the parts they are producing fit within the specifications. Meeting the specifications means that measures on the transmission parts will fall within the desired limits.

**Conformance** means that the manufactured product meets or conforms to the design requirements (that is, the product conforms to specifications).

**Tolerance** means "the allowable deviation from a standard . . . the range of variation permitted in maintaining a specified dimension . . . " (Webster 1990).

The design requirements are drawn on paper sometimes referred to as a **blueprint**. **Built-to-print** and **parts-to-print** refer to building the product (or parts) as specified and drawn on the blueprint.

The aim of the American system is to build its parts to design specifications. Once achieved, the aim is to inspect to determine if the parts pass or fail.

In contrast, the aim of the "offshore system" is to first build the parts to specification as the minimum requirement, and then to continually work on improving the process to reduce the amount of variation. Ford made this videotape to show its engineers that the offshore workers had improved the quality of the product by continually improving the process -- not by being satisfied with building the product "to spec" or by asking for a change in the design specifications.

#### Discussion Questions for the videotape.

#### 1. What is the message in this video?

When the manufacturer had difficulty in meeting design specifications, he asked for a "deviation" from the specification. This means he is asking for permission to produce and ship parts that do not meet specifications.

# 2. What did the manufacturer do when he had difficulty in meeting design specifications?

Asking for deviation from the specifications adds more variation to the product. It is an example of working around the system rather than trying to improve the system.

# 3. What is the consequence of asking for a deviation from the specifications?

It is not unusual for those who manufacture a product to think that a little "slop" is acceptable. This is because some manufacturers think that engineers make the specifications twice as tight as need be. The manufacturer's rationale is that if the specifications are tight and the product meets these specifications, then the product has to be good.

# 4. Why can't you narrow the specifications to obtain improvement?

Narrowing the specifications might give you some improvement on those products obtained by the customer, but at an increased cost. This is because narrowing specifications increases waste since even more products are reworked or scrapped. Also, narrowing specifications does not improve the process.

# 5. What is the reasoning behind asking for a deviation from the specifications?

The message is reduction in variation contributes to continual improvement in quality and increased productivity

6. What are the three important factors that the offshore plant focused on when trying to produce a quality product?

The offshore plant focused on: (1) understanding their production process, (2) producing uniform products, and (3) continually working to reduce the amount of variation in those products.

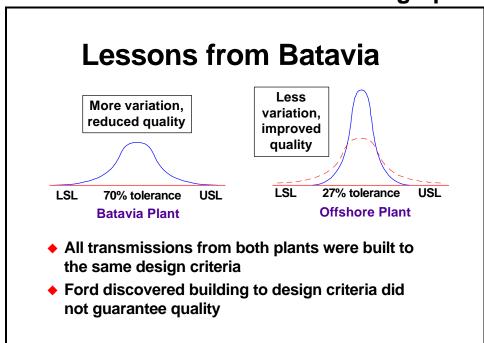
7. What is the one factor that the Batavia plant focused on when trying to produce a quality product?

The Batavia plant focused on meeting the product's specifications. The following is quoted from the videotape: "We worried about specifications; they worried about uniformity. While we were satisfied and proud if we were to print and keeping it to print, they started with the part-to-print and worked on continuous improvement and uniformity of the part."

8. What are some examples in your work where specifications play a role?

In the Batavia video, the floor inspector who made the measurements could not believe the results. The fact that the gauges measured only an infinitesimal piece-to-piece variation did not fit his paradigm. His paradigm said that the gauge must be broken. His paradigm also said that more variation had to exist than was being shown by the gauge.

9. Give examples where you worked to reduce the variation of a product or service even though you were meeting the specifications?



#### **Lessons from Batavia**

 All transmissions from both plants were built to the same design criteria

Here is a simplified graphic of the Batavia lesson. How well the component part in the customer's transmission works could be located anywhere within either of these distributions (curved lines). The Batavia plant used 70 percent of the allowable tolerance, and so if the component part was near the outer edges of the distribution, the chances of transmission problems increased. The outer edges of the diagram are labeled Lower Specification Limit (LSL) and Upper Specification Limit (USL).

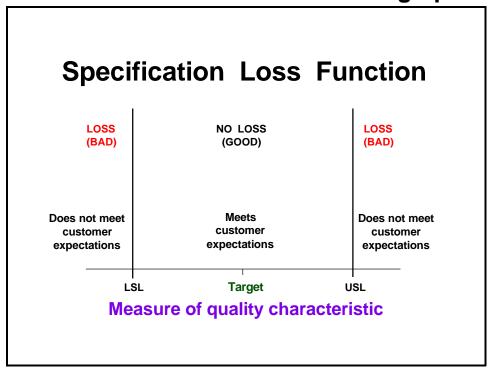
In contrast, look at the distribution for the offshore plant. Still meeting the identical design criteria (specifications), there is far less variation. In fact, the offshore plant used only 27 percent of the allowable tolerance (specifications) for a combination of quality characteristics in the component parts. Therefore, the customer was almost assured of receiving a smoother functioning transmission because of less piece-to-piece variation in the component parts.

Instructor Direction: Point out that the dotted line drawn on the graphic for the offshore plant is the 70 percent tolerance distribution line from the Batavia plant.

## Ford discovered building to design criteria did not guarantee quality

Ford learned a great deal from this experience. It was part of its awakening as to what was meant by achieving quality. Ford found that the component transmission parts built at its Batavia plant exhibited more variation than those built by the offshore plant. The Batavia plant had a much higher risk of not being able to meet the customer's expectations of a smooth functioning, long lasting transmission. Further, the resulting transmission rework increases costs, reduces customer satisfaction, threatens the pride of the plant worker, and reduces productivity, any of which can ultimately drive plants out of business.

In contrast, the offshore plant used the exact same design specifications, but understanding Shewhart's discovery about variation, went to great lengths to continually reduce variation in the component parts. They were always working on **continuous process improvement** by striving for the target value rather than just trying to stay within the specifications. Their customers received high quality, dependable transmissions which translated to fewer failures and repair costs. The offshore plant found that when product quality went up, costs went down, and productivity increased. Is it no wonder that customers preferred the offshore built transmissions? Reduction in variation increased quality. The chain reaction for quality improvement was in place (covered in Module 1, DON Quality Approach).



## **Specification Loss Function**

The traditional approach to product design has most often left the customer out of the design loop. The designer thinks he or she knows what the customer's requirements or expectations are and develops design specifications to fulfill those requirements. The resulting product or service is then defined as either "good" or "bad" depending on whether it falls inside or outside the upper and lower specification limits (inspection). This conformance to specifications has been the traditional way of determining product quality for many U.S. manufacturers in the past.

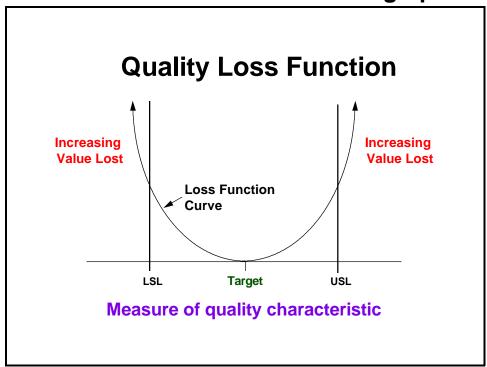
We can use the analogy of the "goal posts" in football to describe this idea. If a football is kicked between the uprights when attempting a field goal (meeting specifications), the team receives three points, whether the location of the ball is dead center or off to the side (Ross, 1988). If the football goes outside a goal post, by the slightest distance, the team receives no points.

★ Additional Information: Phillip J. Ross is the manager of the manufacturing quality systems group at Saturn Corp.

The problem with the goal post mentality is that it does not reflect reality. In life and in business, there is no **sudden** change from good to bad or from perfect to useless. What really happens is that performance gradually deteriorates as quality measures move farther and farther away from the target (Gunter, 1987).

Perhaps the greatest problem with this view is that as long as the quality measures stay within the goal posts (within the customer's expectations), there is no incentive for improvement. The aim of this system is to simply meet specifications. As we saw in Lesson 3-1 (Systems), this is costly.

★ Additional Information: Moen and Nolan (1987, p. 63) state: "The traditional zero defects nature of being within specs would imply a loss function that is zero while inside the limits, and constant while outside the limits"



# **Quality Loss Function**

The goal post view of quality represents the traditional perspective on loss -- the result being either good or bad. In contrast, a quality loss function, developed by Genichi Taguchi, is used to evaluate the relationship between cost and customer satisfaction (quality). The quality loss function is an economically better approach to quality in that it recognizes an immediate loss of quality as soon as product or service quality characteristics move away from the target.

The quality loss function view of meeting customer requirements is based on the premise that **any deviation** from the target results in a **loss in quality**. Loss in quality is related to an **increase in cost**. **The greater the distance from the target, the greater and more accelerated the loss**. The loss is small at first, but increases outward.

★ Additional Information: Genichi Taguchi has been active in Japan's quality revolution since the late 1940s (Gunter, 1987, p. 44).

★Additional Information: The quality loss function curve shown in the viewgraph is one representation. The shape of the curve will change depending upon the data used in its calculation.

The horizontal line represents the possible range of measures with the target representing the ideal value of the measure. The vertical lines show the upper and lower specifications. The curve shows the accelerating value lost as measures deviate from the target. In other words, it represents the amount of value lost in the quality and cost of producing the product or service (Gunter, 1987). The curve of the quality loss function is not arbitrary. Its shape is derived mathematically and will change based on the data used for its calculation (Gitlow, 1989).

In contrast, the closer a product is to conforming to the target value, the better the quality and consequent increase in the ability of the part to function as designed. When this happens, for example, mechanical parts fit together better causing less wear, smoother functioning, and a longer life cycle.

Gains in quality and reduced costs become smaller as you move toward the target. At some point, it may be necessary to consider a cost benefit analysis to decide if it is beneficial to continue reducing variation in the process. At some point, given limited resources, it might be better to move toward improving a different part of the process or to move on to another process improvement effort.

**Caution:** If someone else is working toward continuing to reduce variation and if successful, you may lose market share.

The major importance of the "quality loss function" is that it provides a way to **show the economic advantage** of reducing variation (Ross, 1988). It shows that the cost of a product or service is directly related to the value lost when the quality of the product or service moves away from the target.

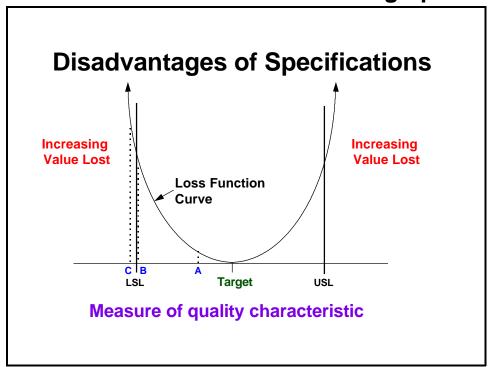
**Instructor Direction**: Remind the students of the value equation they learned about in Module 1 (DON Quality Approach) where, V = Q/\$.

#### Discussion Question :

1. Relate the quality loss function to what you saw in the Batavia videotape?

The more the transmission component parts deviated from the target, the greater the loss in quality and the greater the costs to Ford.

In the Batavia video, you saw the quality manager talking about the importance of focusing on meeting the customer's desire to have a smooth operating transmission. To meet customer requirements, the process managers realized they needed to reduce the variation in the component parts. This reduced variation around the target value translated to fewer warranty repair costs. Thus, it was an economically sounder approach.



# **Disadvantages of Specifications**

When we describe product measures using the quality loss function, it becomes clear that the least loss occurs when a measure meets the target. Loss increases, at an accelerating rate, as measures move away from the target. **Any** variation from the target produces loss, **not** just when the product fails to meet the upper and lower specifications.

Note that Point A deviates only slightly from the target. Because Point A is close to the target, its value loss is relatively small as seen by where it intersects with the value loss line.

Note also that while there is little difference in value between Point B and Point C (both are far from the target), Point C is treated much differently than Point B using the specification loss function. Point C is considered a total loss because it lies just outside the lower specification limit, while Point B is considered acceptable because it lies just inside the lower specification limit.

#### Instructor Direction:

As an option, information can be drawn on the chartpack in the following manner. You can use different colored felt-tip markers to help students learn this point.

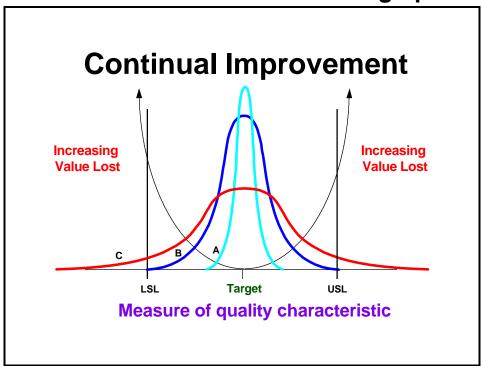
- 1. Using a black marker, draw a horizontal line (quality characteristic measure) and two vertical lines (goal posts), the target, and the loss function curve.
- Using a colored felt-tip marker, mark Point A on the horizontal line and then draw a dashed vertical line from Point A to where Point A intersects the loss function curve. Next, draw a dashed horizontal line from the point on the curve intersected by the dashed line from Point A, to the left vertical line.
- 3. Using a different color felt-tip, mark Point B on the horizontal line and just inside the vertical line. Now draw the dashed lines as you did for Point A. The information immediately following this box supports Point B.
  - In contrast to Point A, Point B is farther away from the target, and as indicated by the dashed lines, reflects a much greater loss in value even though the quality characteristic measure is within the criteria defined by the customer's expectations.
- 4. Using a third color, mark Point C on the horizontal line and just outside the vertical line. Now, from Point C, draw a dashed vertical line parallel to the vertical line until it intersects with the loss function curve. The information immediately following this box supports Point C.

An example of the inadequacy of the specification mentality can be demonstrated by using an example we are all familiar with -- passing or failing a course. If Point C represents failing a course (a grade of F) and Point B represents passing a course (a grade of D), you would have very different consequences, even though the grades given might be close (grades of 59 and 60 percent). The student whose grade is at Point B would pass the course, but the student whose grade fell at Point C would fail. Since there is always error (variation) in measurement, a one-point difference to determine a grade makes little sense.

When you compare the quality loss function with the specification loss function, the **rationale for continual improvement** becomes clear. It becomes clear that we should never be satisfied with producing a product that simply meets specifications. Instead, we should always think in terms of how this product or service can be improved. This idea of continuous process improvement means we must **change our paradigm** from meeting specifications to continually getting closer to the target. The phrase, "If it ain't broke, why fix it?", is no longer acceptable. Our paradigm should be, "If it isn't perfect, improve it!"

#### ★ Additional Examples :

- 1. Consider the effect of temperature on our comfort. Many people feel that the ideal room temperature is 72 degrees. A change in temperature of a few degrees in either direction probably doesn't have much of an effect on comfort. But, a change of as little as 5 to 10 degrees in either direction can bring out the sweaters or short sleeves, depending on the direction of the change. Performance begins to fall off and continues at an accelerating rate as the temperature moves farther away from the ideal temperature.
- 2. If a Pepsi tastes slightly different from one can to another can, the customer probably won't recognize the difference. But, if the variation increases, a point will be reached (different from customer to customer), where customers will notice the taste difference and may decide to stop buying the product. As the change in taste moves farther away from the target, the company will begin to lose more and more Pepsi customers. The cumulative cost lost to the company would eventually cause it to lose market share, threatening jobs, and the existence of the company itself.



# **Continual Improvement**

In the previous viewgraph, we compared two ways of looking at loss: (1) the specification loss function, and (2) the quality loss function. Now, let's look at the **relationship between the quality loss function and variation**.

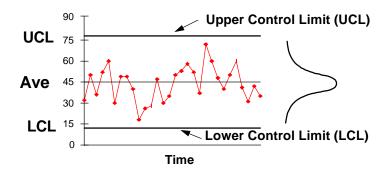
This diagram shows the relationship between variation and value lost for three different distributions. Distribution C shows the greatest loss because it has not only points outside the specifications, but also greater variation inside the limits as determined by the quality loss function. Distributions A and B both lie within the specifications, but Distribution B shows a greater loss than Distribution A as defined by the quality loss function. This is determined from where "A" and "B" intersect the quality loss function curve.

The key to quality lies with producing products as close to the target value as possible. The way to do this is through a relentless continuing effort to reduce variation. You saw this demonstrated in the video that compared the Batavia and offshore plants. While the Batavia plant produced all its transmission parts somewhere within the goal posts (specifications), the offshore plant aimed at producing all its parts at the target value (center of the goal posts).

The Batavia plant thought success meant staying within the goal posts. The offshore plant knew success required continually working at reducing variation.

The "quality loss function" is the rationale for continually working on reducing the variation in our products and services by improving processes. Continual improvement is also the key for innovation in future processes, products, and services. We will look further at the concept of continuous process improvement in Module 3-4 (Knowledge).





 Control Charts allow us to study what is happening in the process

#### **Variation and Control Charts**

 Control Charts allow us to study what is happening in the process

Shewhart developed a method to display on-going variation in process data. The method is called a **Control Chart**. The chart is bounded by an **upper** and **lower control limit** (UCL and LCL). Control limits are calculated from process data taken in sequence, over time. Although control limits are calculated from data, **they do not control anything. They simply reflect variation in the process**.

The process data points shown on Control Charts provide a picture we can study to observe process variation. When all the points fall **randomly** within the control limits, the process is said to be **in control**, as shown here. A process that is in control is stable and its output is predictable. This means that the process will produce the same amount of variation, repeatedly over time, unless something atypical happens or a change is made to the process.

Instructor Direction: When using the word random (below), be aware that the term will be confusing to those who have not had a course in statistics. To a non-statistician, the term "random" might imply data points all over the place, that is, inside and outside the control limits. The statistician's use of the term here refers to a random pattern of data points inside the control limits. Another way to express this is to say there is no discernible pattern of data points around the mean. Be sure to clarify this point to avoid the confusion between the two different uses of the term random.

When data points fall outside the control limits or do not fall randomly inside the control limits, it is an indication that something abnormal or unusual **might** be occurring in the process. These points are **signals** that the processes **may be out of statistical control**. The signals are indicating not to depend on the process to show the same variation over time, and you cannot predict how the process will operate in the future.

In the specification view of quality, the focus is on inspecting the end product to separate **good products from bad products**. In the new view of quality, the focus is on **improving processes**. Shewhart's control chart gives us a way to do this.

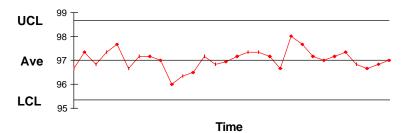
You will learn more about control charts in Module 5 (Basic Process Improvement Tools). We introduced them here so that we can talk about the two causes of variation that can be interpreted from control charts -- **special cause variation** and **common cause variation**. The distinction between these two causes of variation determines when action is needed to reduce the variation, and who is responsible for taking the action -- process workers or process owners.

#### **★** Additional Information:

- (a) Shewhart determined that plus or minus three standard deviations defined the expected range for 99.7% of random/common cause variation. This means that data points falling outside these limits (in the remaining .3 percent of the distribution) are rare and act as a signal to look for a special cause of the extreme values.
- (b) The use of three standard deviations exceeds the usual two standard deviations commonly used in experimental studies. Three standard deviations are used in calculating the control limits to make it extremely unlikely that data points outside these limits would be due to chance. Shewhart's decision to use three standard deviations is sometimes challenged by academic statisticians. But "... the stronger justification of three-sigma limits is the empirical evidence that three-sigma limits work well in practice -- they provide effective action limits when applied to real world data." (Wheeler, 1992, p. 60)
- (c) Using three standard deviations to calculate control limits is referred to as the "three-sigma rule" (rule of three standard deviations). It is also sometimes called the "68, 95, 99.7 rule" referring to the values for one, two, and three standard deviations (Kume, 1988, p. 61).



Causes that are inherent in the process over time, affect everyone working in the process, and affect all outcomes of the process



 Common cause variation exhibits a random pattern of data points that fall within control limits

#### **Common Cause Variation**

Causes that are inherent in the process over time, affect everyone working in the process, and affect all outcomes of the process (Moen, Nolan, and Provost, 1990).

Shewhart studied variation by looking at the distribution of process measures. He determined there are two causes of variation, common cause variation and special cause variation, and that they must be treated differently.

 Common cause variation exhibits a random pattern of data points which fall within control limits

Common cause variation is inherent in the process. It exists as a part of the system. Common causes affect everyone working in the process, and they affect all outputs of the process. Common cause variation is characterized by the **random** pattern of data points within the control limits. When common causes are the only source of variation, we say the process is in statistical control.

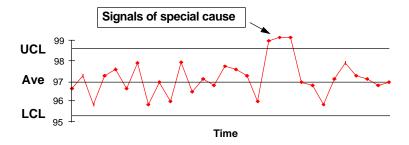
★ Additional Information: In general, common cause variation is identified when all measures (points) fall randomly inside the control limits. The probability is less than one percent (.27 in 1000) that a point falling outside the control limits may still be due to common cause variation. This is an advanced application in the interpretation of common causes and is taught in the Systems Approach to Process Improvement course

This viewgraph shows an example of common cause variation. This Control Chart shows data collected on any generic process. The numbers shown here (95,96,97, etc) can be representative of any process. By taking repeated measures over time, the Control Chart will tell you whether a process is stable, that is, in statistical control, as seen by the random data points inside the control limits.

In the *Systems Approach to Process Improvement* course, you will learn to construct and interpret control charts. By applying some specific tests to control charts, you will sometimes find that the pattern is not random, even though it may appear so. For now, it is more important to remember that when all the data points fall randomly inside the control limits, the process is most likely affected only by common causes.



Causes that are not in the process all the time or do not affect everyone, but arise because of special circumstances



 Special cause variation exhibits a non-random pattern of data points which may include falling outside control limits

#### **Special Cause Variation**

Causes that are not in the process all the time or do not affect everyone, but arise because of specific circumstances (Moen, Nolan, and Provost, 1990).

Special cause variation is due to causes that are not typically part of the process and do not affect everyone. Special cause variation occurs because of "special" or unusual circumstances. One indication of special cause variation is when one or more points fall outside the control limits.

 Special cause variation exhibits a non-random pattern of data points which may include falling outside control limits

Assume that we have already calculated the control limits, and the system is stable. If a data point falls outside the control limits, it is a **signal** to look for a special cause. Sometimes these are easy to identify. Sometimes, identifying the source of a special cause is not so obvious. For example, a high body temperature could be due to infection, but to determine the type of infection might require extensive test procedures.

Remember, data points (measures) falling outside the control limits or showing a non-random pattern inside the control limits (such as several consecutive data points increasing or decreasing in a row) are just signals. They do not tell us why the signals are occurring. You would have to study the process to make that determination. This is an advanced application in the interpretation of identifying control charts and is taught in the *Systems Approach to Process Improvement* course.

Scholtes (1988) writes, "Control charts help you distinguish between variation inherent in a process (variation from a 'common cause') and variation arising from sources that come and go unpredictably ('special causes')."

#### ★ Additional Examples :

- 1. Radio electronics can be used as an example to differentiate between common and special causes. The "noise" present in the atmosphere all the time, and affected by unknown and seemingly random forces, would be considered common cause. When a "signal" (the message itself) is received, it results in a condition beyond the "normal" range of the noise. In actual practice, the "squelch" control is adjusted so that the radio does not respond to the noise but rather so the signals are clearly received. It should be noted that if the signal is not strong enough, the noise is too great, or the detection device is not used properly. Then the message would be lost. The same thing may happen using control charts.
- 2. A ship's galley has been providing meals to its enlisted crew at a cost varying between five and seven dollars a day over the past year. These costs were recorded on a control chart, and all points fell within the control limits. So the system was considered stable and subject only to common cause variation.

After a new chief took charge of the enlisted mess, the meal cost suddenly jumped. The new chief was creating 60 meals more than necessary at each setting. Further investigation revealed that the current manning document listed the number of enlisted at 889 instead of the actual number of enlisted at 829. Special cause variation occurred because the new chief acted on a typographical error in the manning document. By noting the special cause signal that appeared on the routinely kept control chart, the chief was able to detect the sudden change in meal costs and investigate the cause. The process was subsequently changed so that an error like his would not happen in the future.

# **Control Limits and Specification Limits**

- Control limits are determined by the process data and define how the process is functioning
  - The "Voice of the Process"
- Specification limits are determined by design requirements or customer expectations and define the required product or service design dimensions
  - The "Voice of the Customer"

#### **Control Limits and Specification Limits**

By now, it is clear that control limits are not the same as specification limits. These limits are determined by different methods and are used for different purposes.

- Control limits are determined by the process data and define how the process is functioning
  - The "Voice of the Process"

Control limits are statistically derived from data collected over time from the process of interest. They are determined by the process itself. Control limits tell us if the process is stable.

★ Additional Information: Specifications are "a document that states the requirements to which a given product or service must conform" (Quality Progress Glossary, 1992).

- Specification limits are determined by design requirements or customer expectations and define the required product or service design dimensions
  - The "Voice of the Customer"

Specification limits set the range of values, based on engineering requirements and are used to judge the acceptability of a product or service.

We need specifications, but in a total quality organization, they must be developed based on customer requirements. These requirements (quality characteristics) can then be **translated** into product or service design dimensions. Specifications are based on a product or service requirement and are not related to the adequacy of the process. Specifications bear no direct relation to control limits.

Actively pursing customer feedback is frequently referred to as listening to the **voice of the customer**. "The Voice of the Customer can be translated, or operationally defined, in a variety of ways" (Scherkenbach, 1991, p. 13). It is from these operational definitions that quantitative measures are developed. In contrast, the **voice of the process** tells you what the process is capable of doing. It is your responsibility to move the voice of the process toward the target value of the voice of the customer. Listening to your customers can also help you to begin thinking about what type of products or services your customers might want in the future.

## **Stability and Capability**

- STABLE
  - Measures fall randomly within the control limits
- UNSTABLE
  - Measures fall outside the control limits and/or
  - Show a non-random pattern within the control limits
- CAPABLE
  - A stable process that meets customer expectations

#### **Stability and Capability**

To help understand the value of control charts and their relationship to quality (process improvement), you need to know the relationship between **process stability** and **process capability**.

Instructor Direction: You might want to summarize some of the key points the students have learned so far in this lesson.

- There is variation in everything (in products, services, and processes).
- The quality loss function describes the relationship between decreasing quality and increasing cost.
- Variation comes from two causes -- special causes and common causes.
- To identify when these causes are present, we use control charts.
- Control charts tell us how a process is functioning over time.

- ◆ **Stable** (common cause variation only)
  - Measures fall randomly within the control limits

A stable process is one that is in **statistical control**. The amount of variation is said to be stable or in control when all data points (measures) fall randomly inside the control limits. In this case only common cause variation is affecting the process.

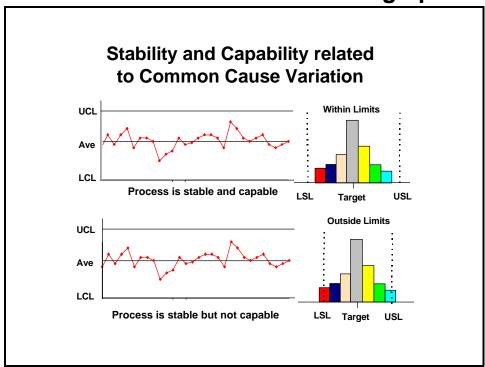
- ◆ **Unstable** (common cause and special cause variation)
  - Measures fall outside the control limits
  - Measures show a non-random pattern within the control limits

An unstable process is one that is not in statistical control. It may have one or more data points falling outside the control limits or points within the control limits that are not random.

#### ◆ Capable

• A stable process that meets customer expectations

A process is considered **capable** if the process is stable **and** the product or service also meets customer expectations. A process does not have a definable capability unless it is stable. **You must establish stability before you can determine capability.** 



## Stability and Capability related to Common Cause Variation

This diagram will help clarify how stability and capability relate to common cause variation.

#### ◆ Process is stable and capable

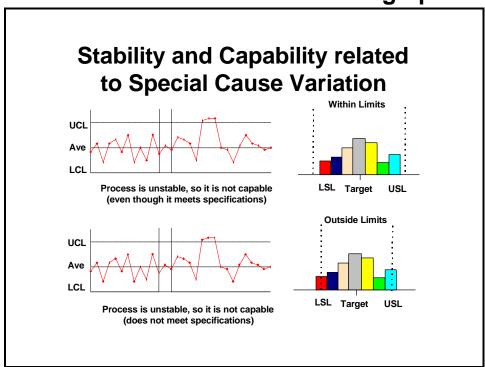
The upper graph shows a process that is stable as defined by the control limits. The data points indicate the variation shown is the result of common causes. The process is also producing output within the specification limits -- thus the process is able to meet customer expectations.

★ Additional Example: An example of a stable process can be demonstrated by bags of ball park peanuts. If each bag is filled with evenly toasted and salted peanuts, then the process is considered stable. If the peanuts satisfy the customers, then the process is also said to be capable.

#### ◆ Process is stable but not capable

The lower graph shows a stable process. However, the process is **not** meeting the specifications so it is not considered capable. Note that there are no special causes affecting the process. The only way to satisfy the customer is to improve the process. No amount of hiring or firing, blaming or encouraging of the workers will result in the product or service meeting the specifications.

★ Additional Example: An example of a stable process that is not capable can be demonstrated again by bags of ball park peanuts. Suppose again that each bag is filled with evenly toasted and salted peanuts (from a stable system), but customers think the peanuts are too salty.



## Stability and Capability related to Special Cause Variation

This diagram will help clarify how stability and capability relate to special cause variation.

#### Process is unstable, so it is not capable (meets specifications)

The upper graph shows an unstable process. Several of the data points signals a possible special cause, even though the process is meeting specifications. Why does this matter? After all, the customer is currently receiving what they want. It matters because since the process is unstable, there is no way to predict if the process will continue to produce what the customer wants. Therefore, we cannot be sure the process is capable of meeting customer requirements in the future.

 Process is unstable, so it is not capable (and it does not meet specifications)

The lower graph also shows an unstable, non-capable process. Statisticians refer to this situation as a "process in chaos." Not only is it not predictable, it isn't even meeting customers' requirements at this moment.

Before you can obtain a stable (common cause only) process, all special causes of variation must first be removed . It is only when the process is stable that action can be taken to continually reduce the amount of common cause variation in the process.

# Benefits of Stable and Capable Processes

- ♦ Benefits of a stable process
  - Prediction of process output
  - Improvement of the process
- Benefits of a capable process
  - Meets customer defined needs
  - Accomplishes the mission

#### **Benefits of Stable and Capable Processes**

- ♦ Benefits of a stable process
  - Prediction of process output

When you have a stable process, you can predict future output with reasonable certainty. A stable process is not a natural state because it will degrade over time. That is one of the reasons control charts are used to **monitor** processes.

#### • Improvement of the process

When you have a stable process, you can examine it for areas where improvements can be made to further reduce process variation. You can also monitor the process to understand how it is functioning. When a process change is made, it is easier to assess the change's effect on the process because you can compare the data efficiently and reliably. Improving common cause systems will improve quality and improve customer satisfaction.

#### ◆ Benefits of a capable process

When a process is stable and meets customer requirements, we have a **capable process**. Process capability should be the aim of any product or service organization. There are additional benefits to having capable processes.

#### Meets customer-defined needs

When you have a capable process, you are meeting customerdefined needs. Customer needs are actively identified and then translated into design criteria. The process is capable when it is able to produce the product or service to this criteria.

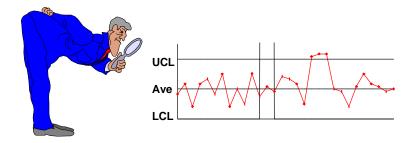
#### Accomplishes the mission

Capable processes are the key to accomplishing the mission. Capable processes mean leaders can plan for the future of the organization. Improving common cause systems will improve quality and customer satisfaction.

The essence of TQL is to reduce variation within customer requirements with the establishment of stable and capable processes. "World Class Quality has been defined by "On Target With Minimum Variance" for the past thirty years! The sooner one wakes up to this fact of life, the sooner one can begin to compete." (Wheeler, 1992, p.146)

We have summarized the key reasons why stable and capable processes are so important. We now need to know who has responsibility for taking action on common and special causes of variation in order to achieve capable processes.

### **Reduction of Variation**



Reduction of common and special cause variation require different types of action

#### **Reduction of Variation**

Reduction of common and special cause variation require different types of action

To reduce variation requires action. The action must be based on data. The action means a change will occur. **Leadership's** responsibility is to take action on the system and make changes to the system based on process analysis . Proper identification of the variation is first required. This can only be done through the attentive use of control charts or other tools.

Who should act to make process changes is determined by the cause (common or special) of variation. The distinction between common cause and special cause variation determines when the responsibility for action (change) belongs to leaders and managers, and when the action belongs to process workers.

### **Responsibility for Reducing Variation**

- Reduction in common cause variation is the responsibility of leadership and management
- Reduction in special cause variation is the responsibility of the process workers (if authority has been delegated to them)
- Quality improvement teams have responsibility by charter to take action on common and special cause variation
- Tampering and underadjusting must be avoided

#### **Responsibility for Reducing Variation**

 Reduction in common cause variation is the responsibility of leadership and management

Studies show that 85 percent of process problems are due to common causes. Scholtes writes,

Quality leadership recognizes, as Dr. Joseph M. Juran and Dr. W. Edwards Deming have maintained since the early 1950s, that at least 85 percent of an organization's failures are the fault of management-controlled systems. Workers can control fewer than 15 percent of the problems. In quality leadership, the focus is on constant and rigorous improvement of every system, not on blaming individuals for problems. In fact, the potential to eliminate mistakes and errors lies mostly in improving the systems through which work is done, not in changing the workers (Scholtes, 1988).

★ Additional Information: Here is a quotation talking about what has come to be known as the "85-15" Rule. McConnell writes "... the great bulk of variation in process outputs is built into the process. In most cases employees are responsible for only (approximately) 15 percent of this variation: causes for the other 85 percent lie hidden in the process. Only management has the power to change the basic process. Therefore, it is only when management understands the process through the use of statistical tools that the potential of the process will be revealed and realized, by reducing variation" (McConnell, 1988, p. 13-14).

Changes to reduce common cause variation must be initiated by top management. Common cause variation is **part of the system**. Since leaders and managers own the system they have the power and authority to make system changes. They have the organizational perspective and the responsibility to see that any changes made to a process meet the aims of the system and do not suboptimize another process within the system. The basic rule is that reducing **common cause variation** is the **responsibility of leaders**.

 Reduction in special cause variation is the responsibility of process workers (if the authority has been delegated to them)

When authorized, reducing special cause variation is the responsibility of the people working the process. (In contrast, leadership works **on** the process.) Because special causes are the result of some unusual situation, they are usually (but not always) fairly easy to identify. Special causes can be removed by those working in the process who have direct involvement and day-to-day familiarity with process operation. The removal of special causes **does not improve** the overall process: **it simply brings the process back under statistical control**.

★ Additional Information: Tribus describes four levels of competence that management must pass through as it evolves toward this new way of thinking. He says that management must move from "unconscious incompetence" to "unconscious competence." He writes: A person must move from being "... unaware that he or she is unable to do what is required" to doing "what needs to be done without thinking about it and explains: 'Doesn't everybody?" (Tribus, 1983).

 Quality improvement teams have responsibility by charter to take action on common and special cause variation

Now, let's integrate the relationship between who has responsibility for taking action on common and special cause variation within the quality improvement teams.

The ESC is responsible for identifying processes that are strategically important to the organization . Once these processes are prioritized, the ESC charters a QMB and defines the team's objective and authority for making process improvements.

As managers of a process, one of the primary roles of a QMB is to take action on variation due to common causes. If any issues are beyond the authority of the QMB's charter, the responsibility for change belongs to the ESC. Both teams are responsible for taking action on common cause variation.

PATs are responsible for taking action on special causes of variation when authorized. PATs also analyze and document processes. PATs often identify common causes of variation, but they do not normally have the chartered authority to make fundamental changes to the common cause process. PATs can, and often do, make recommendations to the QMBs for improving the common cause system.

"The people work <u>in</u> a system. The manager should work <u>on</u> the system" (Tribus and Tsuda, 1983).

This quotation sums it up very well.

#### Tampering and underadjusting must be avoided

People often make two types of errors when trying to improve processes. One error is to treat a common cause as though it were a special cause. This mistake often results in overadjusting or tampering. The second type of error is to treat a special cause as though it were a common cause. This second type of error often results in underadjusting or taking no action to find out the reasons for a special cause.

## • Taking action when no action is needed increases variation

Leaders often have a difficult time accepting the idea that variation in a common cause system is normal. Action taken because people assume something is a special cause when it is really due to system-wide common cause variation is called tampering. You can find more information about tampering in Boardman and Boardman (1994?), Don't Touch that Funnel!

Tampering makes things worse. **Tampering increases variation**. If you treat a common cause as if it were a special cause, or if you change a process based on a single data point, you are tampering and will increase the variation in your process. Fundamental changes to stable processes must be based on **all** the relevant data, not on a single data point.

For example, commands adjust their budgets every year according to their use of funds the previous year. Requisitions for ordnance are based on the use of ordnance for the previous year. Such "single data point" decision-making overlooks a possible trend that may have been underway for several years, or disregards available data on future requirements.

Leaders also tamper when they make changes based on hunches that they think might lead to positive results without basing such actions on process data. To avoid tampering, you must be careful not to create practices, rules, and policies based on single points that arise from normal variation in your process.

#### Underadjusting is a failure to act

Lack of action to remove special causes is an example of **underadjusting**, or failure to act when you should. This might be done if a special cause is treated as though it were a common cause -- if some variation is considered just part of system-wide variation instead of an unpredictable, atypical occurrence.

For example, what if a regular customer suddenly started complaining about late deliveries of products? There may have been an unusual event (new, untrained delivery driver) or there could be a systemic problem rooted in the warehousing process. If no one investigated the cause of these late deliveries and did nothing, this would be an example of under adjusting.

This lack of attention to an out-of-control process will allow the process to remain out of control, which will make prediction impossible and customer satisfaction unlikely.

You can help avoid both tampering and underadjusting by using control charts to guide your actions. Some processes are difficult to chart with control charts, and others are easy. Either way, it is important to chart the data to help guide your decisions. You have to make the decisions anyway, and any decision includes the risk of making a mistake. So, gather as much qualitative and quantitative data as you can to help improve the quality of your decisions.

While avoiding inappropriate actions (such as tampering), management is responsible for taking appropriate action -- improving the common cause system . Recognizing the difference between common causes and special causes and then removing the special causes represent only the beginning of process improvement.

We will now conduct the "Red Bead Exercise" to help you understand the concept of variation a little better.

# Exercise...

## "The Red Bead Experiment"

**Exercise: "The Red Bead Experiment"** 

Instructor Direction: You may choose to conduct this exercise yourself or to show a video. The exercise is a much more powerful learning experience for the students.

**If you decide to conduct the exercise**, go to Module 3-3 Annex," Instructions for Conducting "The Red Bead Exercise" for directions and a sample script.

If you decide to show the video (The Red Bead Experiment and Life, The Deming Library, Volume VII), tell the students they will see Dr. Deming conduct an experiment to demonstrate how the quality of a product or service is controlled by the system -- not by the workers, who are just trying to do their best.

Tell them the setting in this videotape is in a fictitious company we can call "The White Bead Company." The company is in business to package and supply white beads to their customers. The customers will not accept red beads. The employees must meet the customers' quotas if the company is to survive.

#### Discussion Questions :

- 1. What management practices did you see in this exercise that are considered "good" under the <u>traditional approach</u> to management?
- Management provided a clear explanation of what was expected.
- Management demonstrated the procedure and provided a chance to practice on the job.
- Management set clear goals/standards. ("No more than three red beads!" - They set quantitative goals which are even better.)
- Management verbalized exhortations. ("Work harder, do better!")
- Management used bonuses and rewards as a motivation factor.
- Management praised workers.

Other answers you might hear, but are not generally thought of as "good" management practices in the way they were handled are:

- Management disciplined workers publicly.
- Managers fired the poor workers (but still praised them "on good days" - sending a double message).
- Management used fear to manipulate productivity.
- Management used evaluation. "This will go on your record!"

Instructor Directions: On the easel, draw a Cause-and-Effect (Ishikawa) diagram and label five branches: machines, materials, methods, people, and environment. Label the desired effect, "White Beads." Ask the students to identify some of the variables they could study to improve the process, and place the answers on the appropriate branch. Remember, the students have not yet had the lesson on tools, so simply refer to the diagram as looking at the process causes and the desired effect (output).

#### **Some Expected Answers:**

**Methods**: Prescribed procedure, type of vessel, angle of paddle

**People**: Consistency of directions, reliability of inspectors,

micro-management of supervisor

Materials: Beads, recording sheets
Machine: Paddle, vessel or bowl

**Environment**: Fear

## 2. What was the relationship between the workers' performance and the system in which they worked?

The system controlled the workers' performance. The workers had absolutely no control over their ability to reach the quota established by management.

# 3. What cause system was operating, special or common? This is an example of a common cause system. The only way to obtain fewer red beads is to change the system.

- 4. Who is responsible for changing this system?

  Only management can change the system.
- 5. What was wrong with the merit system that rewarded the worker with the fewest red beads?

The worker who received the fewest red beads was just lucky. Merit systems should **not** reward people who are just lucky.

6. What was wrong with putting the worker with the highest number of red beads on probation?

The worker who produced the highest number of red beads should not have been placed on probation. The worker was just unlucky. The system should be on probation. The system produced the red beads; not the worker.

- 7. Why didn't the workers improve when told to do so? Workers cannot improve until the process is improved.
- 8. Is the system bad? What can the workers do about it?

The system producing the undesired red beads was stable. However, it was not capable. Therefore, it is a bad system. The workers cannot change the system. Only management can change the system to meet customer needs.

# 10. Did you see any special causes? Can you think of something that could have happened that would have been a special cause?

A possible answer might be that a worker, made nervous by the manager or the inspectors, could have spilled the beads. Spilling beads could be an example of a special cause. A worker cheating could be another example.

## 11. What value was inspection in the process? Did inspection remove the pink bead?

The only value inspection brought to the process was the possible later removal of red beads from customers' orders. However, this drives up costs. Further, it did not improve the process. Inspection did not remove the pink bead. Remember, the customer ordered white beads.

## 12. How do you think the workers felt when their manager dismissed them?

Angry - they were trying to do their best. Frustrated - they were not allowed to even suggest improvements to the process. Unworthy - their boss dismissed them for poor performance

#### 13. Was there a lot of micro-managing? Did it help?

Their manager stood right over their shoulders and this did not improve their performance one bit.

#### 14. Did management accomplish its aim?

No. The system was not producing the desired quantities of white beads.

## 15. How can management accomplish the aim of the system (to produce white beads)?

Change the system.

### **Lessons from the Exercise**

- Variation in the number of red beads resulted from a system created by management
- Blaming and firing the workers does not improve the system
- Management is responsible for changing the system so that workers can meet customer defined needs
- The role of the leaders is to make it possible for people to identify and remove red beads in the organization

#### **Lessons from the Exercise**

Several important lessons were demonstrated in the red bead exercise.

 Variation in the number of red beads resulted from a system created by management

The red bead exercise demonstrates the influence a system has over the workers' ability to produce a quality product or service. The performance data on process output were plotted on a control chart -- the beads produced by the workers were the result of a **stable** system. However, the process produced too many red beads so it was not capable of meeting customer needs. Customer needs could only be met by inspection, or by changing the process. The system created by management caused the defects - not the workers.

#### Blaming and firing the workers does not improve the system

The workers were helpless in their ability to improve the process or to improve the output. Management set work standards without understanding the concept of a capable process. Workers were rated on the performance of the system. It was **the system that was not able to meet the work standards**. Therefore, the workers were being rewarded or punished for chance occurrence. No amount of blaming, cajoling, exhortations, slogans, fear, or quotas will have any impact on the how the process functions and the resulting quality of the output.

#### Management is responsible for changing the system so that workers can meet customer-defined needs

Until the management of the "White Bead Company" changes the system, the willing workers will not be able to change the quality of their output.

The "White Bead Company" is spending valuable resources on inspectors to ensure that customers' needs are met. But those resources could have been spent on studying and improving the process to reduce the variation in the number of red beads and working with the suppliers to improve the quality of their supplies.

## ◆ The role of leaders is to make it possible for people to identify and remove red beads in the organization

Organizations are filled with red beads. The role of leaders is to make it possible for people in the organization to identify and remove red beads. Our leaders can begin by identifying the processes that produce what our customers want and to systematically work on reducing the variation in those processes. During the exercise, any one of the willing workers could have offered management many suggestions to improve the bead process.

Instructor Directions: After completing the discussion, you may also want to show the videotape, <u>Lessons of the Red Bead Experiment</u> (The Deming Library, Volume VIII). **Do not substitute** this video for the above discussion.

### **Lesson Summary (1 of 2)**

- Variation is part of the System of Profound Knowledge
- Variation is inherent in everything
- Variation can be identified, measured, analyzed, and reduced to improve quality
- The quality loss function is the rationale for continuous process improvement and shows the cost of process variation
- Specification limits and control limits are different
- Variation results from common and special causes

#### **Lesson Summary (1 of 2)**

#### ♦ Variation is part of the System of Profound Knowledge

In this lesson, you learned that variation is one of the four parts of the System of Profound Knowledge. You learned that knowledge about the statistical concepts of variation is required for an organization to consistently and predictably produce quality products or services.

#### **♦** Variation is inherent in everything

You also learned that everything exhibits variation. Therefore, causes of variation are found in the machines, methods, materials, and people that function together as a process to produce a product or service.

#### Variation can be identified, measured, analyzed, and reduced to improve quality

Many different causes contribute to variation in a process. We measure processes to determine the type and causes of variation. In particular, we measure and analyze causes that affect quality characteristics as defined by our customers. This analysis provides us with a picture of how well our processes are meeting those quality characteristics. With this knowledge, we take action to improve our processes by reducing variation.

#### ◆ The quality loss function is the rationale for continuous process improvement and shows the cost of process variation

You looked at the specification loss function for defining quality where inspection was used to determine if the output met design criteria. This contrasted with the quality loss function where quality was defined by how far the measure of the quality characteristic was from the target value. Reducing variation to reach the target value is a never-ending effort in continuous process improvement.

#### ♦ Specification limits and control limits are different

You learned that specification limits and control limits are different. Specification limits define the required product or service design dimensions. Specifications are what design engineers think customers might want. However, specifications do not specifically tell you how well your process is functioning.

Control limits are developed from process data. Control limits tell us how the process is currently functioning.

#### ♦ Variation results from common and special causes

We learned there are two types of variation -- common cause and special cause. Common causes are part of the system. Special causes result from unusual events that are not part of the system.

## **Lesson Summary** (2 of 2)

- Capable processes are required to accomplish the mission
- Management is responsible for reducing common cause variation by working on the process
- People working <u>in</u> the process are responsible for removing special causes of variation

#### **Lesson Summary (2 of 2)**

Capable processes are required to accomplish our mission

You learned about process stability and capability. A **capable process** requires stability. If you cannot predict how the process will function over time, you cannot say whether or not it will meet customer requirements.

 Management is responsible for reducing common cause variation by working on the process

It is the responsibility of management to reduce sources of common cause variation. Because leaders own the processes, they have the authority to take action on the system's processes. Quality Management Boards, composed of process owners, are chartered to reduce common cause variation. They receive guidance from the Executive Steering Committee to ensure optimization of the organization.

 People working <u>in</u> the process are responsible for removing special causes of variation

Action on special causes of variation is taken by those workers involved in the day-to-day process operation. Process Action Teams are chartered to work on specific aspects within the process and to remove special causes when authorized.

# Instructions for Conducting "The Red Bead Exercise"

**Module 3-3 Annex** 

#### **Exercise Introduction**

If you choose to conduct this exercise in class, first watch and study <u>The Red Bead Experiment and Life</u> (The Deming Library, Volume VII) to prepare for this exercise and the discussion that follows.

#### **Staging the Exercise**

Put all the materials and the overhead projector on a table in front of the classroom. Tell the willing workers to stand in a group next to one side of the table. Have the two inspectors and chief inspector stand in a group nearby, but separate from the willing workers. The recorder should stand by the overhead projector. Set up the process similar to that in the Deming videotape.

#### Instructor Directions:

Address the workers. Introduce yourself as their foreman. Ask the recorder to write the names of your production team on the recording sheet transparency. All of you are employees of "The White Bead Company," a low-tech company specializing in white bead production.

#### Sample script for addressing the workers:

"Welcome to The White Bead Company. We are a leading manufacturer of beads. We have a supplier who supplies us with white and red beads. We have just gotten a large order for white beads from a customer. Your job is to produce the white beads for the customer. Is that clear?"

"I am your foreman. Would you please give your names to the recorder to enter on the production log?"

"Are all of you willing to put forth your best effort? Good. Let me tell you about your jobs and the process. Pay close attention."

#### Instructor Directions:

Demonstrate to the six willing workers how they are to do their job. Describe their job and show them precisely how to hold and empty the vessels, and how to "produce" the beads with the paddle.

#### Sample script to demonstrate the job:

"Your job as six willing workers is to understand and do the following: Material comes in these two vessels. Hold the larger vessel with the material in it like this on the long side of the vessel. Hold the vessel 8 centimeters above the smaller vessel. Tilt it to empty it into the other vessel. Pour from the near corner. Make sure you keep the vessel on the same plane. Do not turn it. Don't jiggle it. Let gravity do its work. It's dependable and cheap. Now return the beads into the larger vessel using the same technique. Grasp the vessel on the broad side, hold it 8 centimeters above the first vessel, tilt it, and pour."

"We have work standards here. You are to produce 50 per day; no more, no less. The paddle has 50 holes, as you can see."

"Now, I will teach you how to use the paddle. Follow this procedure exactly, so there are no variations. Grasp the paddle with your thumb and index finger. Dip the paddle into the beads at a 44 degree angle. Gently agitate the paddle in the beads. Draw the paddle out with the axis horizontal and at a 44 degree tilt like this. All 50 of the holes must be filled. Let the excess roll off."

"We have work standards here. We must have 50 white beads per day. No more, no less. I pulled out some red beads to show you what they look like."

#### Instructor Directions:

Provide directions for the following scenario: The willing worker should take the paddle and walk over to the two inspectors. The two inspectors independently count the number of red beads produced and record the results in silence on their note pads. The chief inspector compares the results. If there is no discrepancy in the counts, the chief inspector announces the count and dismisses the worker by saying, "Dismissed." The worker should then walk back to the table and dump the beads from the paddle back into the larger vessel.

If there is a discrepancy in the two counts, one of them is wrong and the chief inspector is responsible. The chief inspector is responsible for all mistakes. The two inspectors have to recount the red beads. When agreement is reached, the chief inspector announces the count and dismisses the worker, who then dumps the beads back into the larger vessel.

#### Sample script for the apprenticeship period:

"There is a period of apprenticeship training for practice. After that, no talking, just do your job. Failure to follow these instructions absolutely will result in dismissal. You will have a job as long as your performance is satisfactory, and only that long. You will have merit raises for good work, and will be put on probation for poor work."

"During apprenticeship, you can ask any questions you want to clarify the procedures. Would any of you willing workers like to practice? After the apprenticeship is over, you can't ask any questions!

#### Instructor Directions:

Go through the apprenticeship period. Ask if any of the willing workers would like to practice the procedure before the real work begins. Critique (praise or berate) each willing worker's technique. Pay particular attention to how the vessel is held, how the beads are poured, and how the paddle is held, jiggled and removed from the vessel. Check to make sure that the pouring vessel is 8 centimeters above the other vessel, the pouring vessel is not jiggled, the paddle is tilted at 44 degrees, and there are exactly 50 beads on the paddle. Give all the workers who want to practice a chance to do so. **Do not record these trial results.** 

#### Sample script for ending the apprenticeship:

"Do all of you understand your jobs? Do you understand that there will be no departures? Our procedures are rigid! All of you will do precisely what I have trained you to do. Your apprenticeship is over! You have been well trained in the procedure. You now know your job. Are you ready to go to work? Are you ready to try hard and give your best? Remember, we reward good performers and penalize poor performers."



#### **Day 1: Three Bead Quota**

#### Instructor Directions:

Begin with the first willing worker. Critique workers according to how they do their job and the results they get.

#### Sample script for day 1:

"Today is our first day of work. Since you've all had excellent training, management decided to put a limit on the number of red beads you produce. Our goal is three red beads; that is, your limit is three red beads each, no more. What happens when you get more than three red beads? It goes on your record! The retirement plan is very simple. You may retire before your time."

"Make sure you keep the vessel on the same plane. Do not turn it. Your job is to make white beads, not red ones. There should be no variation! Remember, there is no variation in the procedures."

#### Sample script for praising or berating the workers:

**For workers with poor technique:** Hold the vessel on the long side! . . . Eight centimeters, not nine, not seven! . . . Don't jiggle the vessel! . . . Count the red beads independently! . . . Inspectors, don't talk to each other.

For workers with poor results: Our customer wants white beads, not red ones! . . . Weren't you watching? Why did you produce red beads? . . . I can't understand it! . . . All right let's have improvement. Remember our goal is three red beads! . . . Don't you know, you should do it right the first time? . . . How did you do it? I don't know how you could do it! . . . Doesn't make any sense. Procedures are rigid! . . . Your job is to produce white beads, not red ones!...

**For workers with good results:** Good technique, excellent technique. Were all of you watching how they did it? . . . Good worker, taking the job seriously! . . . Rapid learner, you get a merit raise!

#### Sample script for the end of Day 1:

"Can't understand it. All this variation! We are on the merit system here. This means you are rewarded for good performance. Willing worker (name), you had the best result. For that, you get a merit raise. Worker (name), you are on probation! I can't understand it. Don't you want a job here?"

"I don't understand it. Our procedures are fixed, rigid! Everybody works under exactly the same procedures, uses the same equipment, works in the same plant. There should be no variation. I don't understand it!"

#### Day 2: Zero Defect Day

#### Instructor Directions:

Ensure all the data was recorded by the recorder. Begin Day 2 production. Continue to praise or berate the workers.

#### Sample script for day 2:

"Management has proclaimed that today is "Zero Defect Day." That means no red beads! Do you hear me? No red beads today!"

#### Sample script for praising or berating workers:

For workers who do worse today than yesterday: Can't understand it. You did worse today than yesterday! . . . Don't you know, today is "Zero Defect Day?" Pay attention! . . . Don't you know your job depends on your performance? Do it right the first time! . . . One of our best workers. What happened? . . . You're on probation!

**For workers who improve:** Good worker. Really taking your job seriously! . . . Congratulations! That's what I call an improvement! . . . Why didn't you do that yesterday? . . . Keep up the good work! . . . You get a merit raise for the greatest improvement! . . . Was on probation and improved. Started to take the job seriously!

For workers with very poor results: Stop the line! What happened? Study it. Fix it!

For workers with very good results: Why haven't you been doing this all along? If you can do it, anybody can.

For the worker with the lowest number of red beads: (Name), you get a merit raise.

For the worker with the highest amount of red beads: (Name), you are on probation. Can't understand it. Today was "Zero Defect Day" and look at how many red beads you had. Such poor performance! There should be no variation! Doesn't "Zero Defect Day" mean anything to you? The CEO wants a complete report on today's results.

#### Day 3: Pay Bonus

#### Instructor Direction:

Begin Day 3 by reading the script.

#### Sample script for day 3:

"The CEO is very disappointed in your results for yesterday. Management is watching today's figures very closely! Costs are exceeding revenues. Management has decided to give a \$500.00 bonus to the worker who gets 3 red beads or less. Your jobs are dependent on your performance! It is entirely up to you! Unless there is substantial improvement, today may be your last day on the job."

#### Instructor Directions:

Continue to praise or berate the workers. Here are some more suggestions.

#### Sample script for praising or berating workers:

For workers with less red beads than they had before: That's what I like to see. Continual improvement. Excellent job. You get a merit raise! . . . Obviously learning something. Shows a continuous record of improvement! . . . Steady improvement. We're proud of you!

**For workers with more red beads than they had before:** What's wrong? I'm really disappointed in you. Can't you try harder? . . . Keep this up and you may not have a job for long! . . . You're on probation.

For workers with varying numbers of red beads: I can't understand this. You made (number) on the first day, (number) on the second day, and (number) today. This variation is incomprehensible. It doesn't make any sense! . . . Look at that variation. There should be no variation!

#### Day 4: Keep The Best Workers

#### Instructor Direction:

Begin Day 4 by reading the script.

#### Sample script for beginning Day 4:

"I've told you this before: Management is watching the figures. Unless the results are substantially better today, management will shut the plant down and you will all lose your jobs! So pay attention, be serious, do your job exactly as you have been trained."

"Remember, your job performance is entirely up to you. I can't see why there can't be zero defects!"

#### Instructor Directions:

Continue to praise or berate the workers according to their high or low results, their techniques, and so-called "trends," as you did during the previous days.

Have the recorder total the number of defects for each worker and compute the daily average for each worker and the group as a whole. Keep the 3 best workers, dismiss the rest.

#### Sample script for discussing keeping the plant open:

"I warned you that unless the plant improved substantially, management would shut the plant down. Well, one of our top managers came up with a brilliant idea and it has been endorsed by the executive board. The plant will not be shut down. We will have a new style of management. The plant will be kept open - with the best workers!"

"The top (number) workers can stay. The other (number) are dismissed. Thank you very much. It goes on your records. Go pick up your pay."

"You, the (number) best workers, will keep the plant open. Congratulations! By the way, you must work two shifts to meet the production goal."

#### **Day 5: Double Shifts**

#### Instructor Direction:

Begin Day 5 by reading the script.

#### Sample script for beginning Day 5:

Just think of it, management let us keep the plant open - and with the best workers. What a team! We got rid of the laggards. Now we'll get somewhere!

#### Instructor Direction:

On Day 5, the (number) workers work two shifts. Each worker has two turns. Continue praising or berating the workers.

#### Sample script for the end of Day 5:

Today we ran the plant with our best workers and the result was not what we expected. What can I say? We had a total of (number of red beads).

The executive board called an emergency meeting and decided to close the plant down after all. You're all dismissed. We'll keep your name on file in case something opens up. Thank you.

#### Instructor Directions:

Create a control chart from the data recorded. Plot the points on the control chart transparency, calculate the average (x-bar), the proportion (p-bar), and the upper and lower control limits (UCL and LCL). Round the UCL and LCL to the nearest whole number.

If you have a co-instructor, have the other instructor create the control chart while you lead the exercise.

The following statements are based on the assumptions that all of the points are within the control limits and there is no run (a pattern of seven or eight points in a row). You can briefly mention some of these statements before returning to Viewgraph 3-3-24 to conduct a more thorough discussion on the Lessons of the Red Bead Exercise. Also ask the questions starting on page 3-3-55 to debrief the exercise.

#### Statements about the control chart:

"Let's look at the results. All of the points are between the upper and lower control limits. This is a pretty good sign that we have a state of statistical control. We can safely say that we have a stable process. I see no pattern of seven or eight points in a row, or "run." This is as close to a common cause system as you will encounter."

"So what does this tell us? What about the way the results wander around the average? The willing workers used the same procedure and the same tools, yet their results varied. This variation came from the system."

# The White Bead Company

**Our Mission:** To produce White Beads for our customers

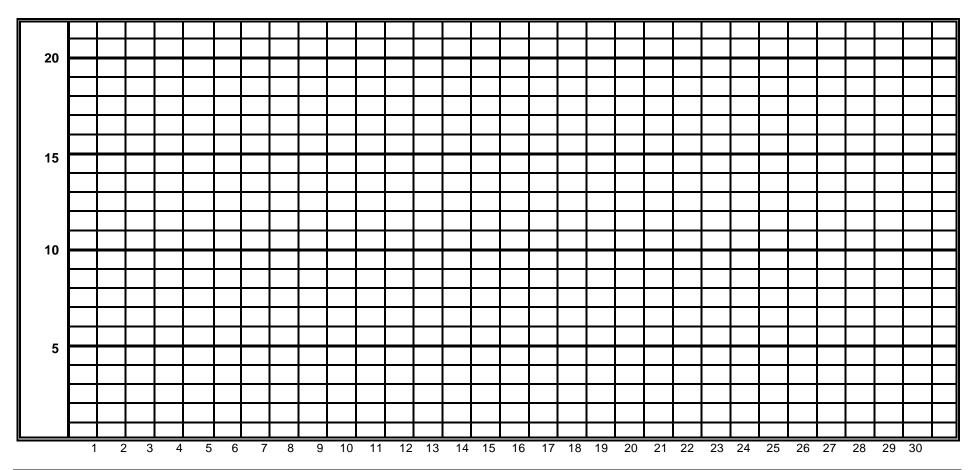
**Production Lot Size**: 50 Beads per worker per day

Employee	Day 1	Day 2	Day 3	Day 4	4 Day Total	Day 5	5 Day Total		
Daily Total									
Daily Average									

Inspector #1:	Recorder:	
Inspector #2:	Foreman:	
Chief Inspector:	CEO:	

### Red Bead Control Chart

<u>Type of Chart:</u> Attribute Data <u>Unit of Measure:</u> Number of Defects (Red Beads)



Cou	ınt																												
Total # Red Beads ( )						Total # Red Beads ( )					<b>UCL= X</b> + 3						UCL:												
X =	 (# Wo	rkers	s) X (	# day	— = /s) (	)	=	<b>P</b> = (	# Wr	rkrs) 2	X (# c	dys) >	〈 (Lot	sz)	= — (	)	L	.CL=	χ.	- 3 √	<b>X</b> (	1 - P	)			LCL	:		